Observing the Entire Universe: Big Bang to the Dark Sector

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The concordance model of cosmology, in which the Universe began in a hot **Big Bang**, underwent a period of rapid **inflationary expansion**, and is currently dominated by a mysterious **dark sector** made up of **dark matter** and **dark energy**, represents a magnificent triumph in observational ant theoretical cosmology. The next decade will see a further refinement of this model with CMB data from Planck and galaxy images and spectra from Euclid and WFIRST (along with a plethora of other projects) fleshing out our understanding of the history and evolution of the Universe. However, questions will certainly remain, and a full census of the contents of the Universe is within our grasp in the next 30 years.

Observational Prospects: In the 2020s and beyond, there will remain a vast amount of information about the origin, expansion, and constituents of the Universe encoded in the CMB as well as photometric and spectroscopic observations of galaxies A survey with enough sensitivity to detect the unambiguous signature of inflation in the polarization of the CMB would give us unprecedented constraints on the period of inflation while also giving us information related to the subsequent accelerating expansion of the Universe. Plans and technology development for such a survey are already forming via the CMBPol mission concept and on-going ground and balloon-based observational efforts.

While we will have measured the detailed properties of large sample of galaxies by the mid 2020's (e.g. $2x10^9$ photometric measurements with Euclid), it is within our technological reach to complete this census by measuring the photometric, spectroscopic, and morphological characteristics of the **entire** population of galaxies in the Universe that are not obscured by our own Milky Way. That is, **we could perform a nearly complete census of the ~10^{11} galaxies in the Universe**. A large (>10m) space telescope could resolve nearly the entire population of galaxies and with a degree-scale field of view and critically sampled focal plane, we could obtain optical and near infrared (0.5-2.5 μm) photometric and spectroscopic observations of a large fraction of these 10^{11} galaxies, up to z~10. Within this resolved photometric, spectroscopic, and 3-D spatial clustering information is encoded the expansion history and growth of structure needed for the ultimate test of dark energy and gravity models. Missions such as Euclid and WFIRST are ideal stepping stones on the road to a complete census in the 2030-2040 timeframe.

Technological Needs: In order to fully exploit the information encoded in the polarization of the CMB, we need to press ahead with the development of arrays of polarization-sensitive bolometers and receivers. A full census of the galaxies in the observable Universe requires 1. lightweight, deployable mirrors to enable a wide field, ultra-stable >10m space telescope; 2. continued development of optical and near-infrared detector arrays for degree-scale gigapixel arrays; 3. development of optical (or similar high bandwidth) download capabilities; and 4. Multiplexing capability for >10^4 simultaneous, multiplexed spectroscopic observations.

	10 yr	20 yr	30 yr	Tech needs
CMB/Inflation	Tech develop	All-sky CMB Polarization measurements, and improved theoretical models of inflation		Polarization sensitive bolometers and receivers
Dark Sector	WFIRST/Euclid	~10^{11} photometric measurements	~10^{11} spectroscopic measurements	Deployable mirrors, multiplexed spectra, optical downlink, advanced detectors